Petroleum Hydrocarbon Vapor Intrusion Investigations

Case Studies

prepared for:

U.S. Environmental Protection Agency
Office of Underground Storage Tanks
Petroleum Vapor Intrusion Work Group Webinar
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by
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Acronyms

CFR	Code of Federal Regulation
DTW	Depth to groundwater
EPA	Environmental Protection Agency
GW	Groundwater
LNAPL	Light Non-Aqueous Phase Liquid (also called free product)
LUST	Leaking Underground Storage Tank
OUST	Office of Underground Storage Tanks
PHC	Petroleum hydrocarbons
PM	Project Manager
PVI	Petroleum vapor intrusion
SV	Soil vapor
VI	Vapor intrusion
VMP	Vapor monitoring point
VMW	Vapor monitoring well
VW	Vapor well

OBJECTIVE

- **Determine when petroleum vapor intrusion (PVI) pathway may be complete**
- **Determine need for PVI investigation, mitigation**

METHOD & SCOPE

- **Characterize sites**

  - Define full extent & degree of contamination (required by 40 CFR Part 280)

  - Collect continuous soil cores: describe soil type, moisture, visual/olfactory presence of PHCs, headspace

  - Depth to groundwater: spatial, temporal

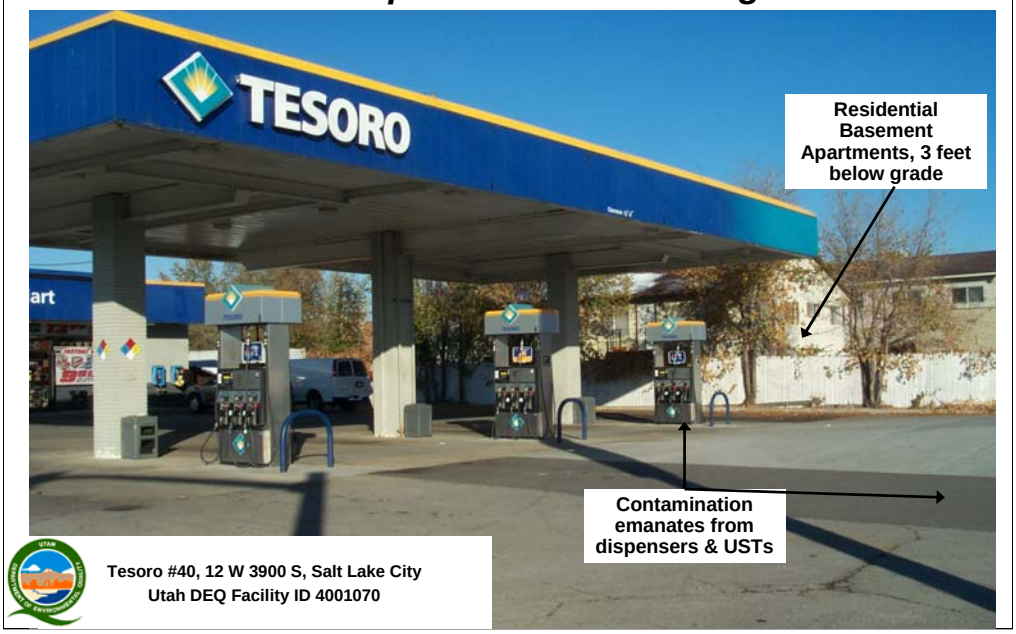
  - Land use, groundwater use

  - Identify receptors: building type & size, basements/crawl space, utilities, sumps, elevators, other relevant features)

Implementing agencies are required to know as much as possible about a site in order to make informed decisions about impacts to public health and the environment, and to determine cleanup options. Basic information is required and routinely obtained from PHC-contaminated sites. Defining full extent and degree of contamination and identification of potential receptors are fundamental elements for understanding if any exposure pathway is complete.

Case Study 1

Sub-Slab Vapor Intrusion Investigation



Very high concentrations in groundwater at 8 feet deep, soil contamination, residential apartment slab and living space at 3 feet deep.

Information about Utah LUST sites are available for public review at http://www.environmentalresponse.utah.gov, go to Interactive Map and search on Utah DEQ Facility ID.

Case Study 1: *Front View of Apartments*

The apartment complex houses families comprised of adults and many children all of whom are home most of the time. Total area of the complex is 2275 ft2 (35ft x 65ft). Dissolved concentrations in GW range up to 10,000 ug/L benzene and 46,000 ug/L TPH at 8 feet below grade, and the apartment living space is 3 feet below grade.

Case Study 1

Representative Residential Scenario

This residential situation involves large families that have occupied these apartments for the past 10 years (since ~2000), nearly 24 hours per day, 365 days per year. There are currently many babies and small children living here. Picture in the lower right shows contractor, regulator and a curious child-resident. This PVI investigation is representative of how intrusive such investigations are.

Case Study 1

Sub-Slab Vapor Intrusion Investigation

Tesoro #40, Salt Lake City, UT

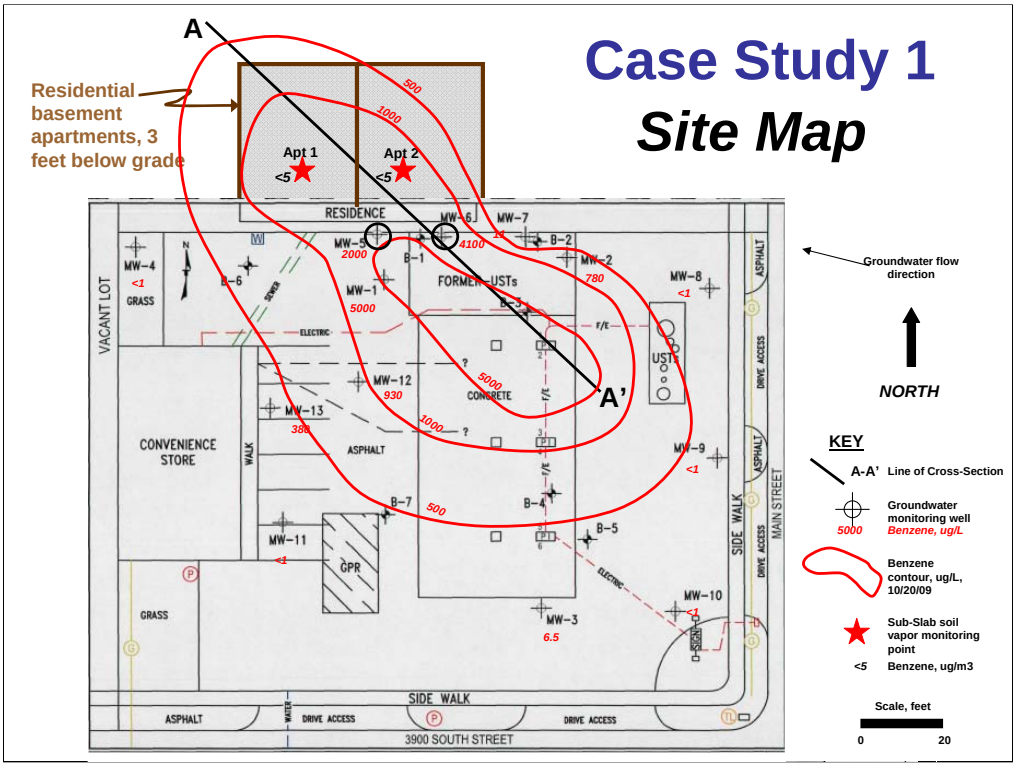
- **Full extent & degree of contamination defined on-site & off-site**
- **Groundwater 8 feet below grade**
- **PHC concentrations in groundwater:**
  up to 10,000 ug/L benzene and 46,000 ug/L TPH
- **Adjacent residential apartments 3 feet below grade**
- **Course of Action: *Conduct sub-slab soil vapor sampling***

Case Study 1 is an operating station responsible for a very high-strength dissolved gasoline plume at a shallow depth. The plume extends off-site beneath two residential basement apartments. Because of the very high dissolved concentrations at shallow depth, the logical approach to addressing the potential for vapor intrusion was to install sub-slab vapor monitoring points in both apartments.

In less than 1 year of release discovery, the full extent of soil-phase and dissolved contamination was fully defined, receptors identified, 3 rounds of GW monitoring were conducted, nearby residents contacted, and sub-slab vapors sampled beneath the adjacent residences.

Contractor: Terracon, Salt Lake City, Utah, Ben Bowers contact

UDEQ Facility ID 4001070, Release ID MJK

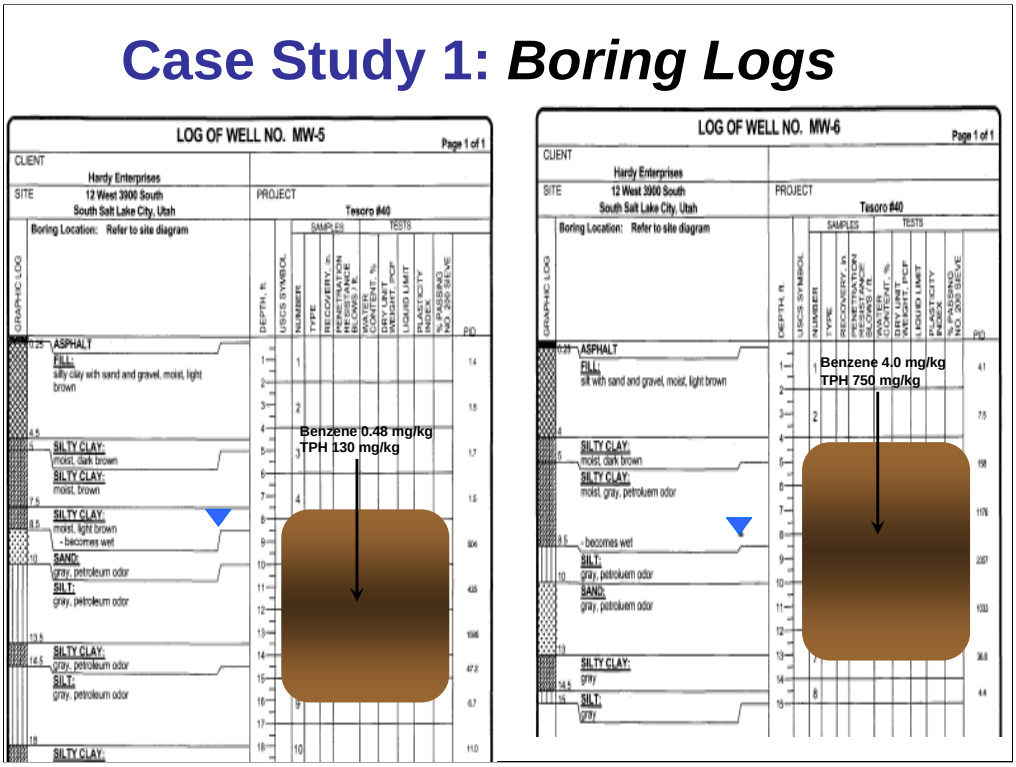


UDEQ directed the full delineation of contaminated soil and groundwater, and installation of sub-slab vapor monitoring points. Depth to groundwater is 8 feet below grade, and the 10/20/09 GW monitoring event shown here indicates dissolved benzene concentration beneath apartment slabs ranges from 1000 to 5000 ug/L. Concentrations are much higher during Spring high water table conditions.

The apartment foundation slabs and living space are 3 feet below grade, and because very high dissolved concentrations exist beneath the apartments, one sub-slab vapor monitoring point was installed in each apartment.

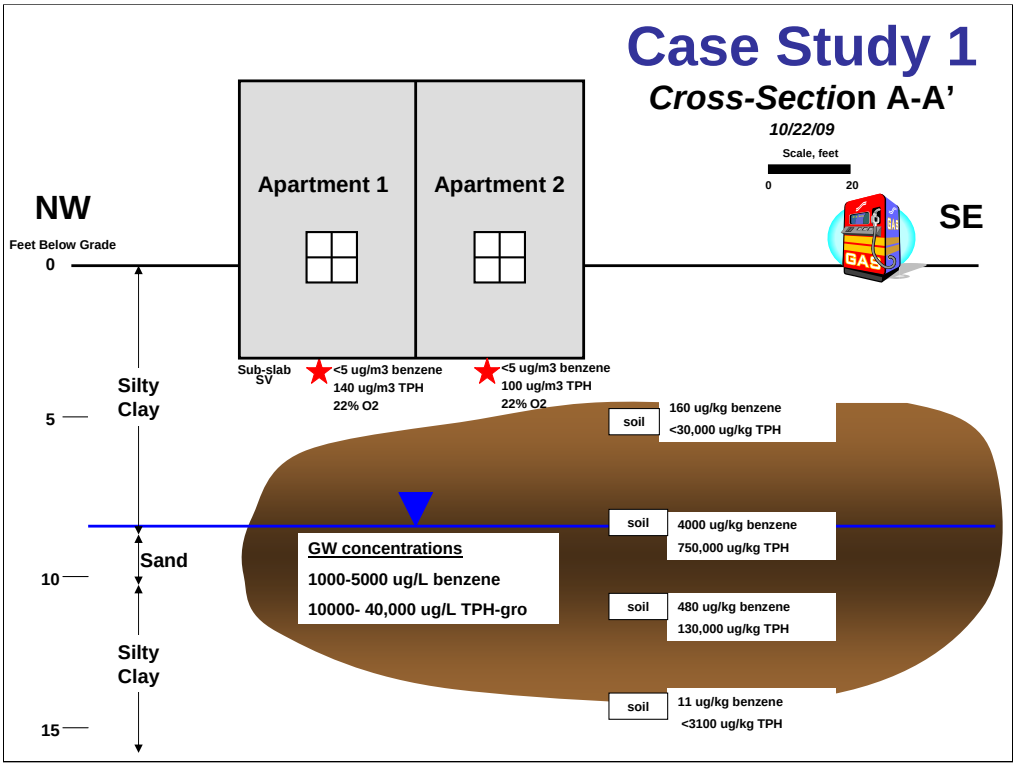
There are 5 feet of soil separating the slab from the top of groundwater based on the characteristics of the nearest borings/monitoring wells MW-5 and MW-6.

Case Study 1: *Boring Logs*



Boring logs from MW-5 and MW-6, those closest to the apartments, show the contaminated soil zone within the zone of water table fluctuation, commonly called the “smear zone.”

Soil contamination is evidenced by photoionization detector (PID) measurements and visual observations of petroleum odor and staining. Contaminated soil is shown by the shaded areas. The highest concentrations in soil samples are shown for benzene and TPH.

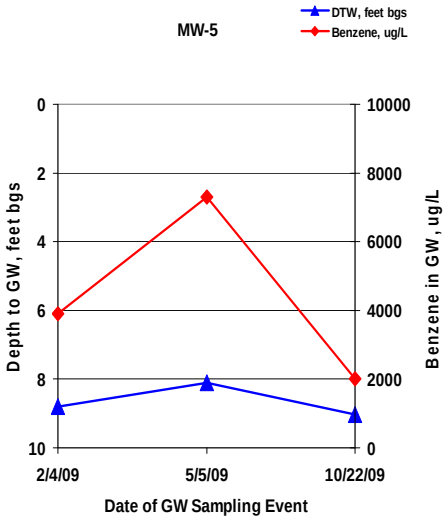


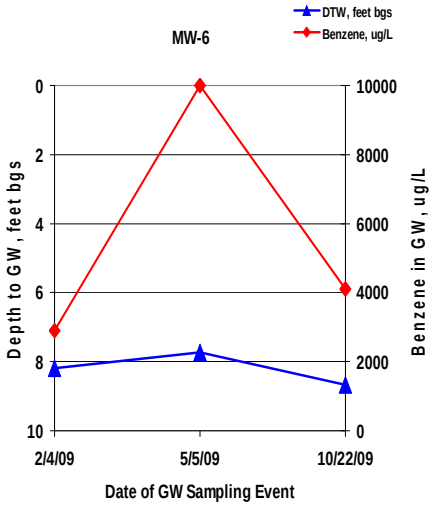
This cross-section of the affected area shows contamination in close proximity to the building, enough evidence to warrant a vapor intrusion investigation.

A cross-section of the affected area shows groundwater and soil contamination in close proximity to the building in high enough concentrations to warrant a vapor intrusion investigation. GW is 8 feet deep, and dissolved benzene in GW is 1000 to 5000 ug/L, TPH up to 40,000 ug/L. Soil data (brown shading) shows high adsorbed phase contamination near the groundwater surface, commonly called the “smear zone.” The extent of soil contamination beneath the buildings could not be measured and is estimated from the nearby soil borings.

Although sub-slab benzene exceeds the EPA OSWER 2002 Draft VI guide value of 3.1 ug/m3, this exceedance is insignificant. The sub-slab TPH vapor concentrations are well below indoor air risk-based screening levels and the PVI pathway is therefore considered incomplete.

Case Study 1: *Hydrographs*





Hydrographs such as this help show the effects of seasonal groundwater fluctuations on corresponding dissolved contaminant concentrations. They also help verify locations of contaminated soil zones. These hydrographs show that slight decreases in depth to water case significant increases in contaminant concentrations.

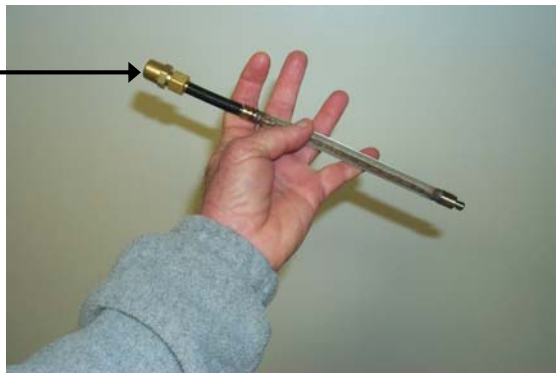
MW-5 and MW-6 are a few feet away from the apartments. Sub-slab vapor points were sampled shortly after the 10/22/09 GW sampling event. Another vapor sample event and concurrent GW sampling event are scheduled for Spring 2010 when the water table is higher and dissolved PHC concentrations are higher.

Sub-Slab Point Installed in Very Tight, Personal Space (laundry room)

Sub-Slab Point Installed using 1-inch hammer drill bit

Sub-slab vapor monitoring points were installed using simple techniques and accepted standard practices.

6-inch stainless steel screen set within & below slab



Surface completion of sub-slab vapor monitoring point

Case Study 1
Summary

- **Cautious decision to sample sub-slab based on high dissolved concentrations in close proximity to living space**
- **Contaminant vapors fully attenuated with 5 feet of soil between sub-slab & top of soil contamination (3-8 ft interval)**
- **Vapor intrusion pathway not currently complete *(based on only 1 round sub-slab SV data)***
- **Further actions: Continue monitoring dissolved GW plume & sub-slab vapors; potential in situ cleanup if necessary**

Although the PVI pathway is not complete, the UDEQ will continue monitoring PHC concentrations in groundwater and develop a cleanup plan for contaminated soil and groundwater. Sub-slab vapors will be sampled at least one more time, or at intervals that best represent seasonal changes in subsurface conditions.

Case Study 2

Subsurface & Sub-Slab Vapor Intrusion Investigation

Hal's, 138 West Main, Green River

Utah DEQ Facility ID 5000270

Free product gasoline up to 2 feet thick is detected on GW and extends off-site beneath a motel and café/bar (shown by red outline). The buildings both have basements and are very close to the top of groundwater and free product.

This site has undergone extensive characterization, cleanup, research and long-term monitoring. Over 40 GW MWs have been installed and monitored since 1991; 18 years of groundwater data. 11 Vapor MWs were installed in 2002 and have been monitored through 2009.

Brief Site History:

-**40,000 to 130,000 gallons gasoline impacted groundwater**

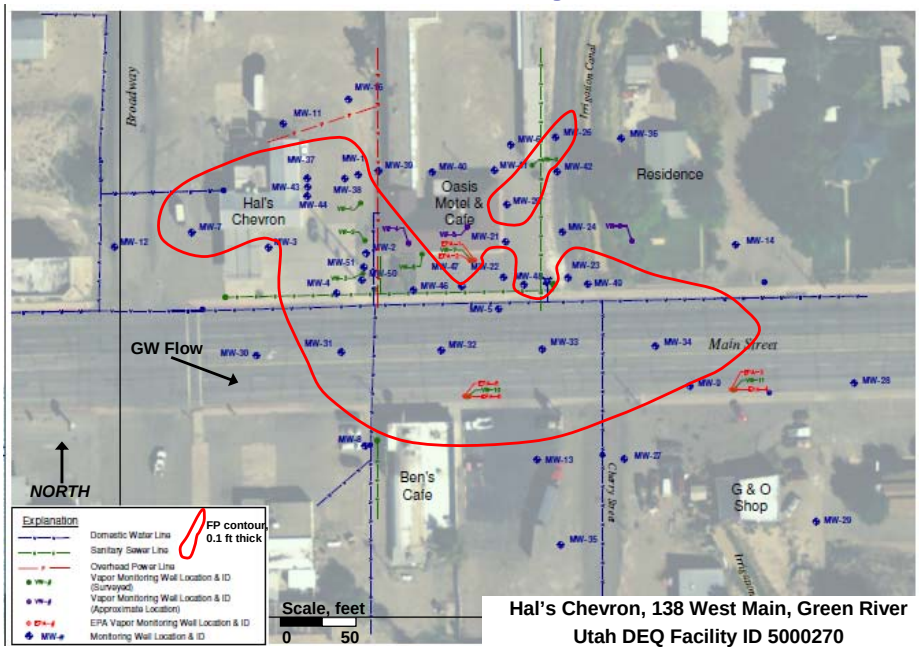
-**26,000 gallons free product removed 1993 to 2004**

-**$1.3 million spent**

-**Vapor intrusion pathway has never been complete. No complaints from building occupants.**

-**Vapors are attenuated**

Case Study 2



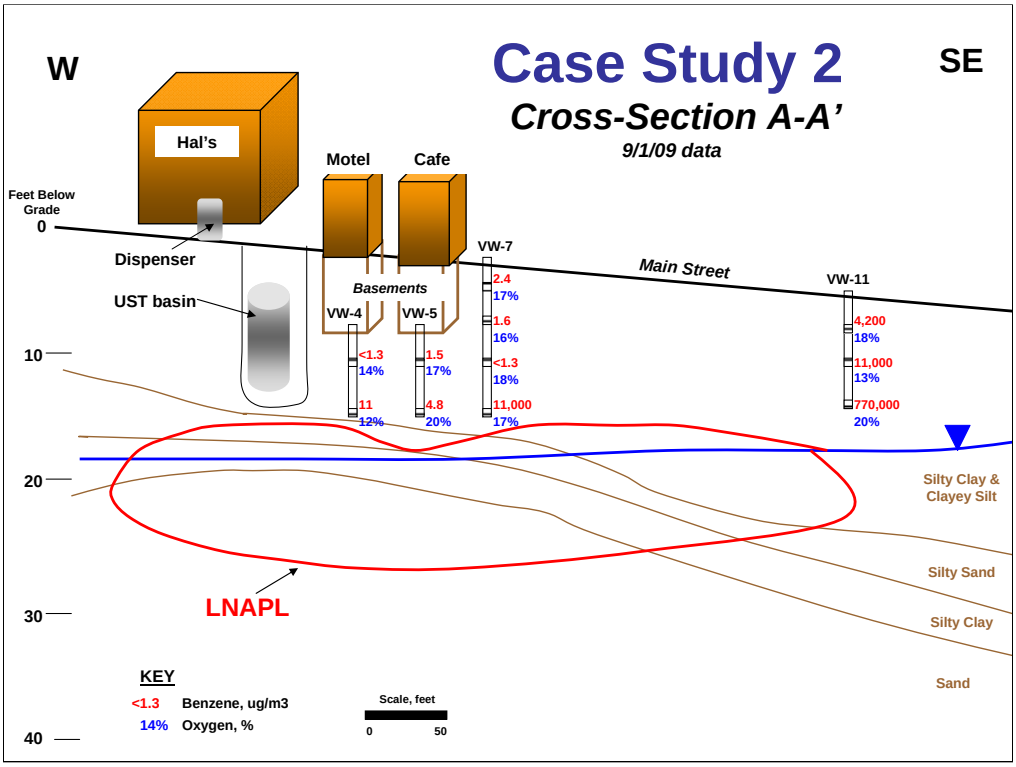
Hal's Chevron, 138 West Main, Green River
Utah DEQ Facility ID 5000270

Map view showing City of Green River and lateral extent of free product measured on 9/1/09. The free product extent has looked much like this since 1998, so the plume is no longer stable and or migrating.

Case Study 2

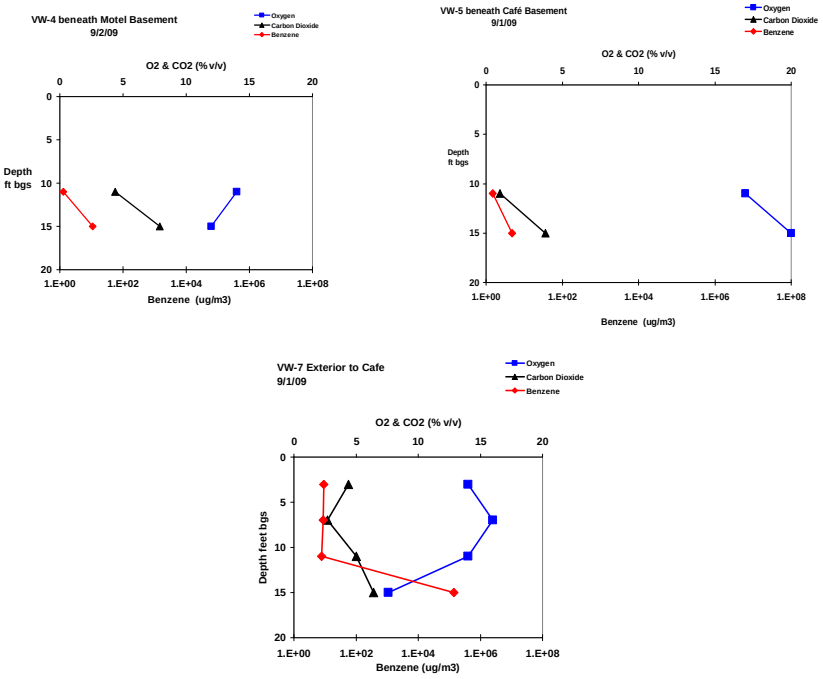
Subsurface & Sub-Slab Beneath Buildings

VW-4 and VW-5 are multi-depth vapor monitoring wells installed beneath the basements of the motel and café. VW-7 was installed 5 feet outside (exterior) the building footprint.



Multi-depth soil vapor benzene and oxygen concentrations are in vapor wells installed along the LNAPL plume axis. VW-4 and VW-5 are multi-depth vapor monitoring wells installed beneath the basements of the motel and café. VW-7 was installed 5 feet outside (exterior) the building footprint. The vapor intrusion investigation indicates that vapors are fully attenuated with less than 5 feet of clean overlying soil. VW-11 was installed down-gradient. The sample event shown on this diagram exhibits high vapor concentrations but anomalous high oxygen concentrations, which we suspect is due to leaks at the completion points.

Case Study 2: *Vapor Profiles*



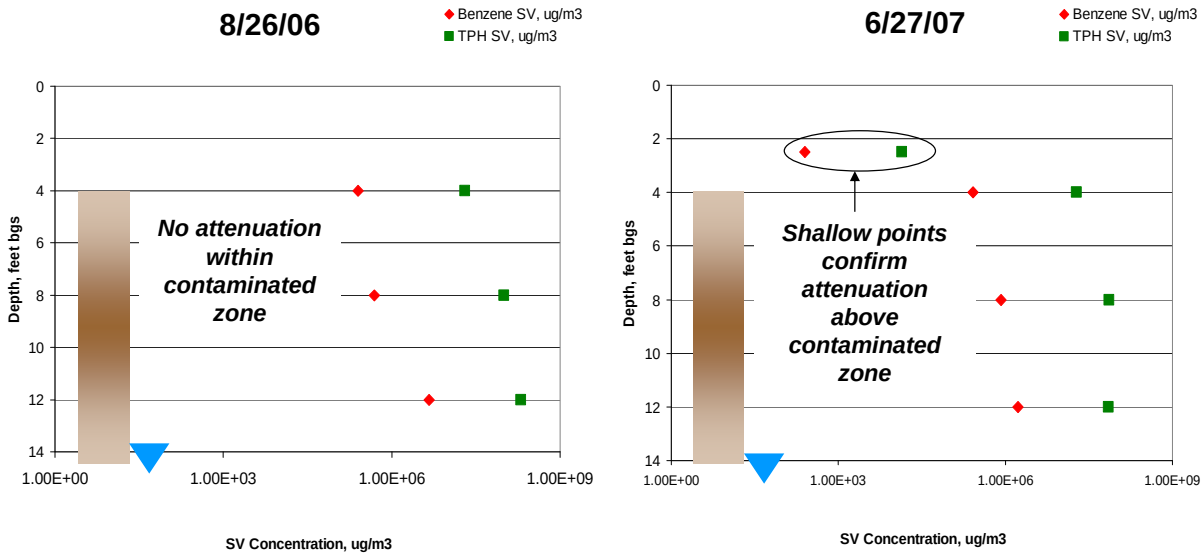
Vapor profiles of VW-4, VW-5 and VW-7, multi-depth vapor monitoring wells installed beneath the building basements and 5 feet outside (exterior) the building footprint.

The vapor intrusion investigation indicates that vapors are fully attenuated with about 4 feet of clean overlying soil.

Example of Apparent Non-Attenuation due to no Shallow Soil Completion Point

Importance of Shallow Vapor Completion Points

VW-11
Hal's, Green River, Utah



This slide shows benzene and TPH vapor profiles of vapor well VW-11 from two different sampling dates. Vapor concentrations are very high within the contaminated soil zone (patterned area) and, from the 8/26/06 sampling date where the shallowest vapor sample was obtained from 4 feet deep, vapors appear to not attenuate below the overlying receptor. However, on 6/27/07, vapor samples obtained from 2.5 feet deep showed nearly complete vapor attenuation. Leak testing confirmed the good integrity of each completion point.

Some practitioners maintain that vapor completion points set too shallow (some say <5 feet deep) may be subject to short-circuiting or otherwise drawing in atmospheric air, causing a false-negative effect on vapor analyses. Others argue that this effect is not occurring at most sites because, according to standard sampling practices, vapor samples are obtained relatively quickly ("grab samples") and draw vapor in from the area directly around the completion point. Studies in Utah show that only faulty completion points or unnecessarily long sampling times result in drawing in atmospheric air. VW-11 is an example that shows the benefits of shallow completion points out-weighing the perception that short-circuiting might occur.

Case Study 2

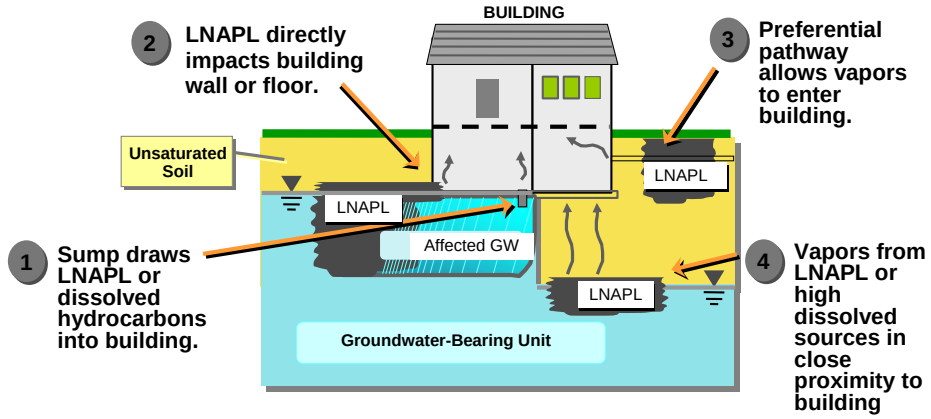
Summary

- **Contaminant vapors are fully attenuated with <5 feet of clean soil between sub-slab & top of LNAPL**

- **Vapor intrusion pathway is not complete**
- **Further Actions: Continue monitoring LNAPL, dissolved and vapor phase contamination, possible in situ cleanup depending on funding availability**

Causes of Petroleum Vapor Intrusion

Regulatory & Industry Experience



KEY POINT: **Vapor intrusion caused by LNAPL, contaminated soil, or high-dissolved sources in direct contact or close proximity to buildings/receptors**

after Todd Ririe, 2009 (AEHS Amherst conference; API)

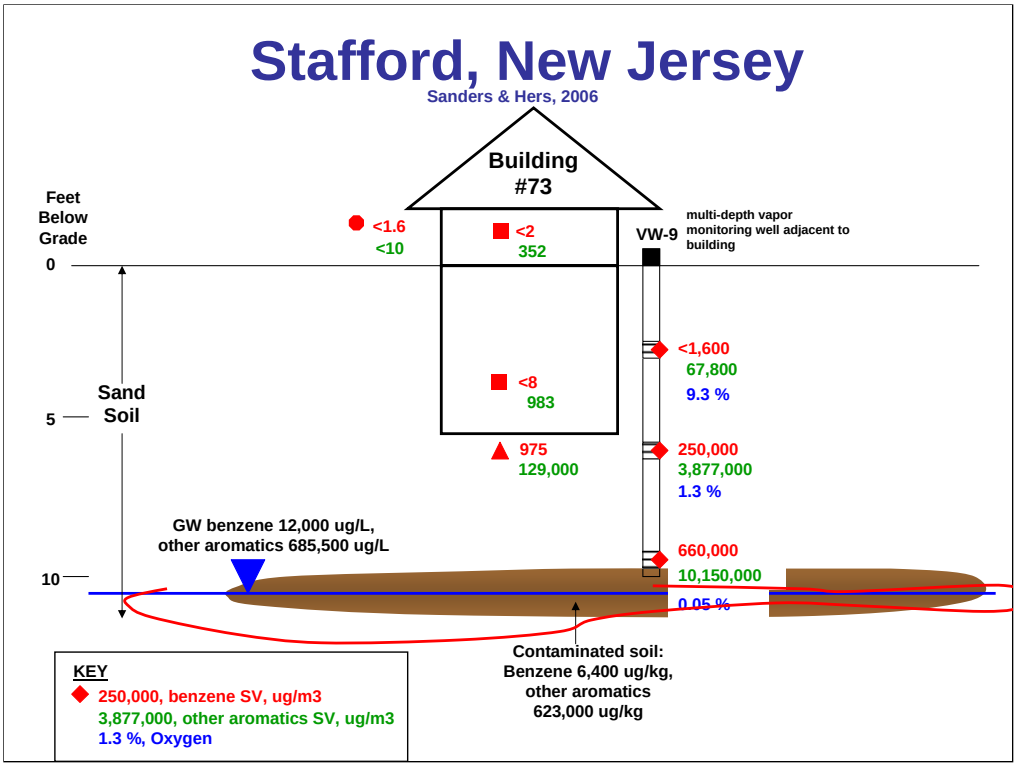
Based on practical field experience and published literature, petroleum vapor intrusion impacts are generally associated with:

1) Direct contact of LNAPL or very high dissolved concentrations to building sumps, elevator shafts
2) Direct contact of LNAPL or very high dissolved concentrations to a building foundation
3) Direct contact of LNAPL with preferential pathway (e.g., improperly-sealed utility lines)
4) Close proximity of LNAPL or very high dissolved concentrations to a building foundation

<u>Key Points:</u>

Current USEPA VI guidance provides GW screening concentrations for benzene and other petroleum hydrocarbons in the low ug/L range (i.e., 5 ug/L for benzene). These low screening concentrations are not consistent with regulatory or industry experience that vapor intrusion impacts are not associated with low concentrations of petroleum hydrocarbons dissolved in groundwater.

The science available today is sufficient to support the development of separate screening criteria and attenuation factors for petroleum and chlorinated VOCs.



This slide shows that while PHCs biodegrade regardless of the presence of the building, very high source concentrations in close proximity of the building slab did result in vapor intrusion by the recalcitrant compounds but not above their risk-based concentrations. Compounds of PVI: MTBE and the aliphatics Cyclohexane and 2,2,4-Trimethylpentane.

Risk-based concentrations exceeded for MTBE (IA RBSL 3130 ug/m3), Cyclohexane, whose RfC (RfDi) is 1.7, similar to Toluene which has an IA RBSL of 5220 ug/m3. 2,2,4-Trimethylpentane does not have an RfC so it is cautious to assume it is represented by heptane which has the lowest RBSL in the C8 aliphatic group of 219 ug/m3.

Ogden Mini Mart, Ogden, Utah

Utah DEQ, 2006

Free product on shallow GW lies between 0 and 3 feet directly beneath the on-site building. Vapor intrusion was exacerbated by the building's out-of-code HVAC system which did not permit free air exchange.

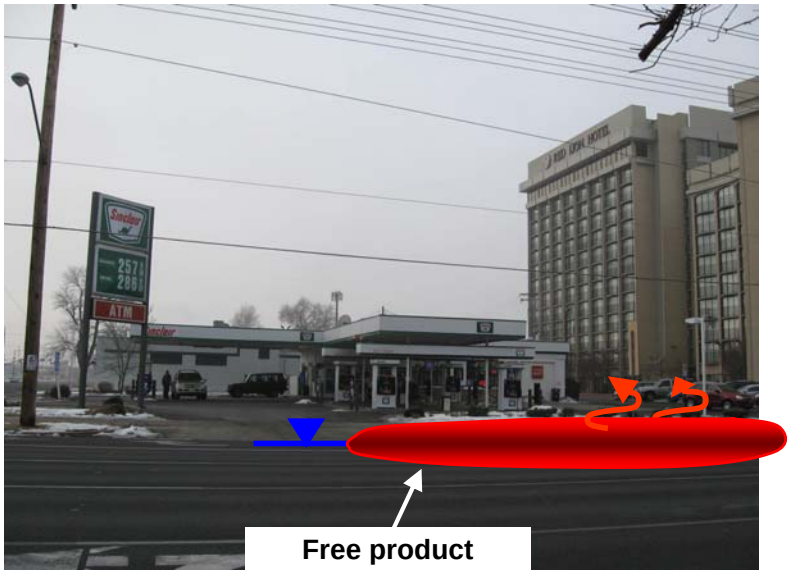
Joes' Service/Quincy Building Ogden, Utah

Utah DEQ, 2009

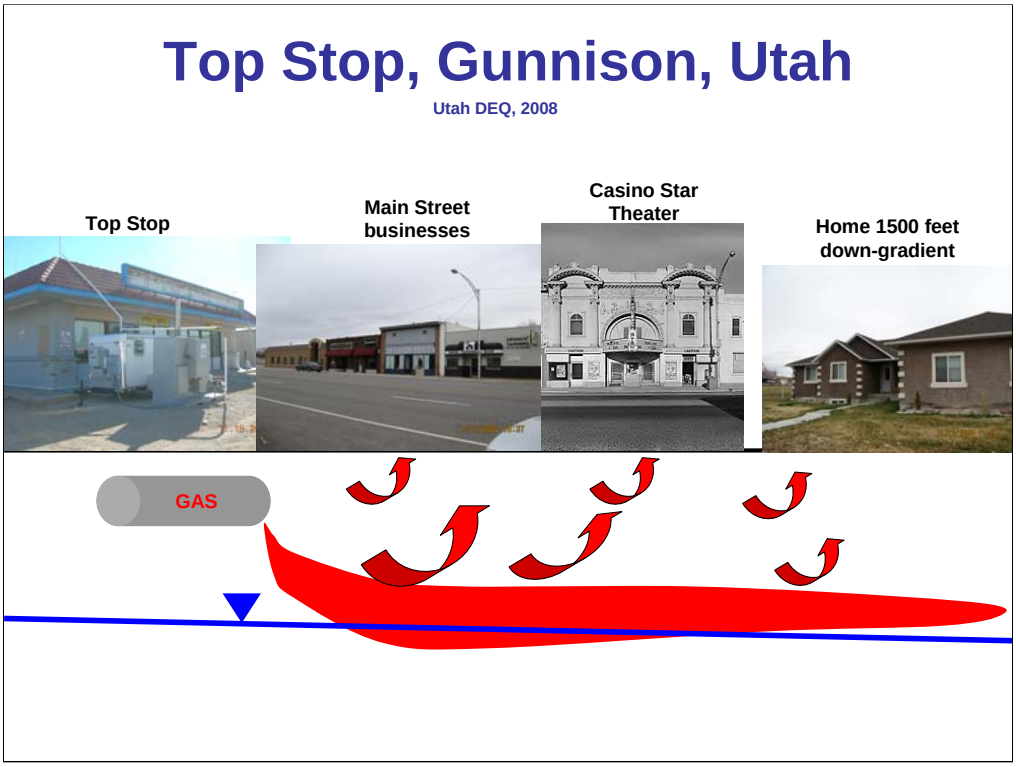
Very high dissolved PHC concentrations in shallow groundwater impacted the adjacent Quincy Building via an improperly-sealed sewer line.

Sinclair/Red Lion Hotel
Salt Lake City, Utah

Utah DEQ, 2009



Free product on shallow GW emanating from the Sinclair station was drawn into the 13-story Red Lion Hotel by the hotel de-watering sump. The hotel elevator shaft may also have been a preferential pathway for vapor intrusion. HazMat teams were deployed, contaminated soil was excavated and removed, and the UST system replaced.



A catastrophic release of up to 20,000 gallons of gasoline. The sudden release could not displace water-saturated soil and vapors transported quickly. Numerous businesses along Main Street and homes up to 1500 feet down-gradient of the release were severely impacted. The UDEQ received complaints from building occupants of strong petroleum odors inside the buildings.

Conclusions

- **Sites and receptors must be fully characterized**
- **Thickness of clean soil overlying sources must be determined**
- **Exercise good judgment in determining when PVI investigation is necessary**

THANK YOU

ACKNOWLEGMENTS

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